JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 102, NO. D24, PAGES 28,911–28,913, DECEMBER 26, 1997

Comparison of BOREAS and Atmospheric Environment Service humidity sensors at Meadow Lake, Saskatchewan

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Abstract. A comparison of co-located humidity measurements by two different sensors, a Campbell Scientific 207F (at an operational Atmospheric Environment Service autostation) and a Campbell HMP35 (used in the Boreal Ecosystem-Atmosphere Study research mesonet) suggests that the older sensor, the 207F, has significant errors.

1. Introduction

The collocation of a suite of Boreal Ecosystem-Atmosphere Study (BOREAS) mesonet instruments and operational Atmospheric Environment Service (AES) instruments (a Campbell Scientific autostation) at Meadow Lake in Saskatchewan from early in 1994 permitted us to compare their meteorological sensors. The AES instruments, including the temperature and humidity sensors (a Campbell Scientific 207F) at Meadow Lake, are located inside a standard Stevenson screen on a wooden stand. The BOREAS sensors installed on a short tower by the Saskatchewan Research Council (SRC), have a Campbell HMP35CF temperature and humidity sensor (made by Vaisala), a Gill radiation shield, and are not aspirated [*Shewchuk*, 1996]. We noticed that although pressure, windspeed, and temperature agreed closely between both sets of measurements, there were systematic significant differences in humidity and hence mixing ratio, which we discuss here.

2. Comparison of Thermodynamic Variables

The BOREAS measurements are 15 min averages, while the AES measurements are sampled every 15 minutes, but this difference is not important here. We compared pressure, wind speed, temperature, and humidity variables. The bias in pressure between the two measurement systems is very small: typically less than 0.2 mbar (not shown). The bias in wind speed is also negligible (not shown).

Figure 1 shows the monthly mean diurnal cycle of temperature for the BOREAS and AES instruments for June 1994. The agreement is satisfactory: there is a small afternoon bias of 0.2°C, with the AES instrument higher. However, the 1 month average of the diurnal cycle of RH, shown in Figure 2, shows a systematic bias in the morning after sunrise. RH, as measured by the BOREAS sensor, falls faster than the AES measurement. This phase shift in RH in the AES data from roughly 1200 to 1900 UTC introduces a significant midmorning peak in mixing ratio q shown in Figure 3, because there is no corresponding phase lag in the temperature curves in Figure 1. The AES data show a sharp peak of q at 1500 UTC, which is about 1 g Kg^{-1} higher than that shown by the BOREAS sensors. This 1500 UTC peak in q is a characteristic of most of the operational AES stations in the area. In contrast the BOREAS sites typically do not show this feature (however, they are also, except for those at Meadow Lake and Saskatoon, not at 2 m but above a forest canopy). We believe the BOREAS data are the more accurate for humidity. The Campbell 207F sensor with the AES autostation apparently does not desorb water nearly as efficiently as the newer sensor after reaching saturation at night.

The humidity sensors have some other significant differences. Figure 4 plots RH of the BOREAS Vaisala sensor against the AES sensor: the crosses are for UTC > 1200 which covers the evening rise of RH, and the open circles are for UTC < 1200, which covers the morning fall of RH. Alternate data points have been omitted for clarity. The high bias in the morning, as humidity falls, approaches 10%, while in the evening, the sensors agree well. Two other biases can be seen.

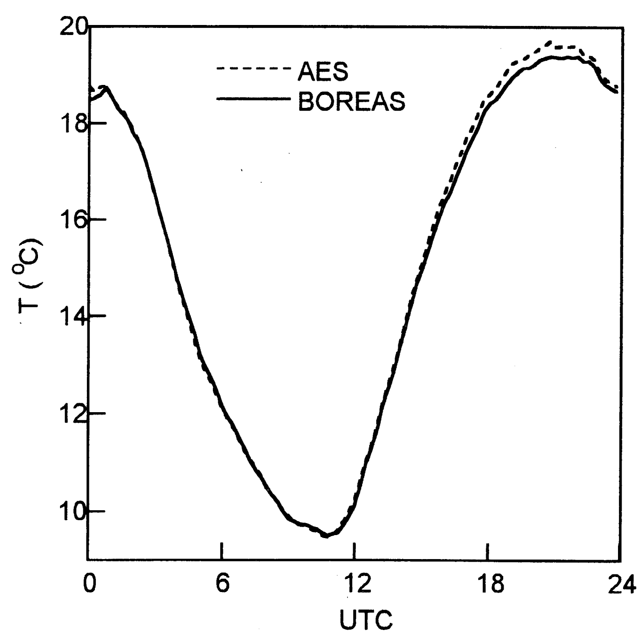

Figure 1. Monthly average diurnal cycle of temperature (T°C) at Meadow Lake, Saskatchewan, for operational Atmospheric Environment Service (AES) instrument and BOREAS mesonet sensor for June 1994.

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Paper number 96JD03094.
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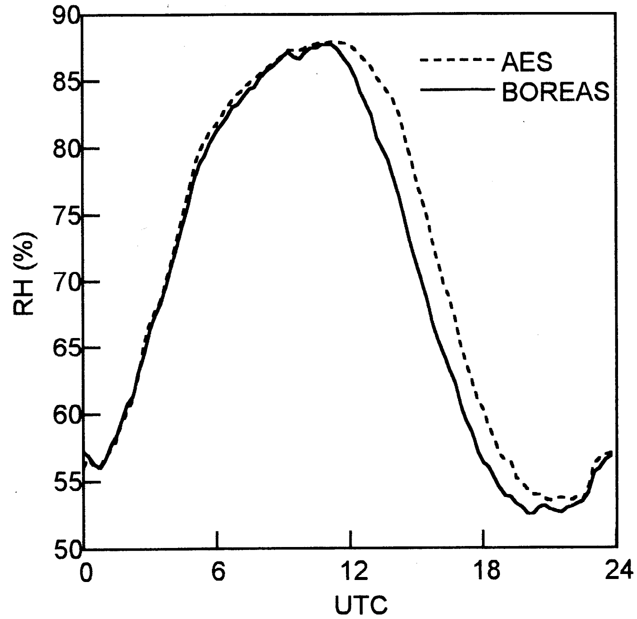

Figure 2. As Figure 1 for relative humidity (RH %).

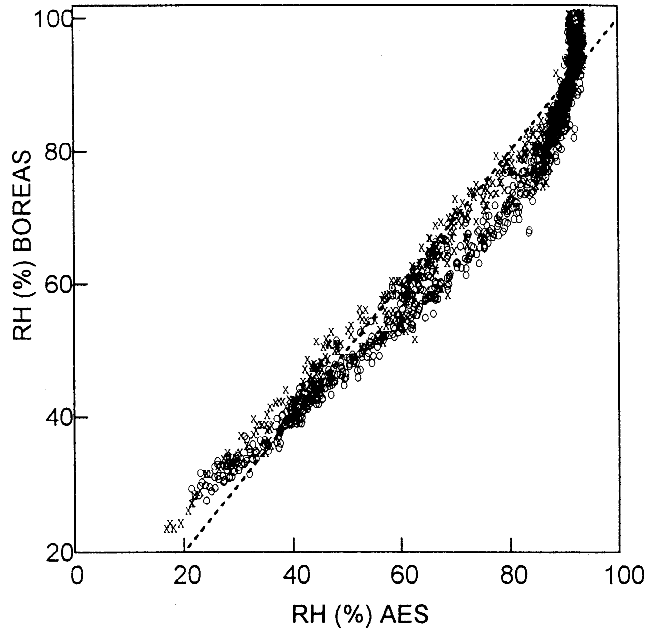

Figure 4. RH of BOREAS sensor against AES sensor for the month of June 1994. Open circles are data for UTC < 1200 (morning) and crosses for data UTC > 1200 (evening).

At high humidities the BOREAS sensor reaches 100%, whereas the AES sensor tops out at about 93%. The BOREAS HMP35 sensor is more likely to be accurate in this high humidity range. At low humidities the AES sensor is about 5% drier than the BOREAS sensor. In this case we do not know which is the more accurate, except that it is probably again the more modern HMP35 sensor. Note, however, that the HMP35 Vaisala sensor on the BOREAS mast has a quoted accuracy of only ±5%.

Figure 5 illustrates in a time series all the biases that are seen in Figure 4, as well as one further difference. The ordinate is a decimal Julian day sequence of 15 min data points for 5 days from the beginning of the month of June 1994. The plateau in the AES RH at 93% can be seen where the BOREAS sensor peaks near 100%. On days 154 and 155 the lag in the fall of RH from its maximum near sunrise can be clearly seen. Late on day 152 the low humidity bias between the BOREAS and AES sensors can be seen. Late on day 153, the bias is the reverse, but the response of the BOREAS sensor to changes in RH is much larger. This greater sensitivity of the BOREAS sensor to RH fluctuations at high humidities can be seen at other times as well.

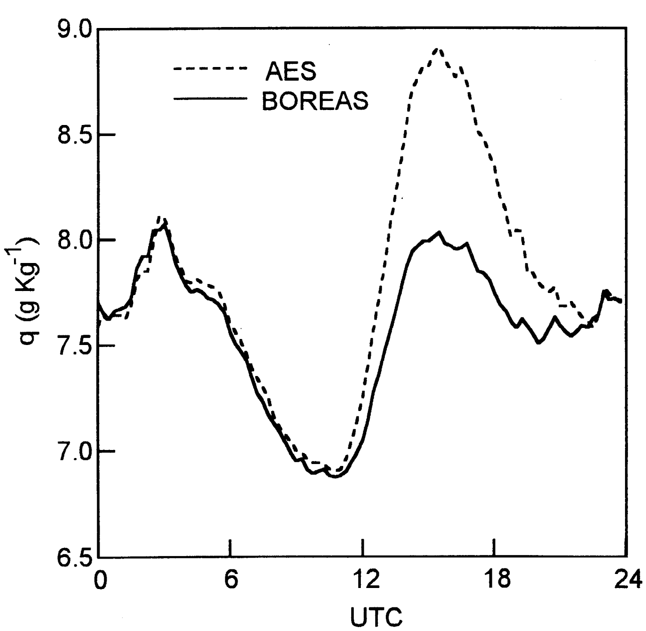

Figure 3. As Figure 1 for mixing ratio (q g Kg^{-1}).

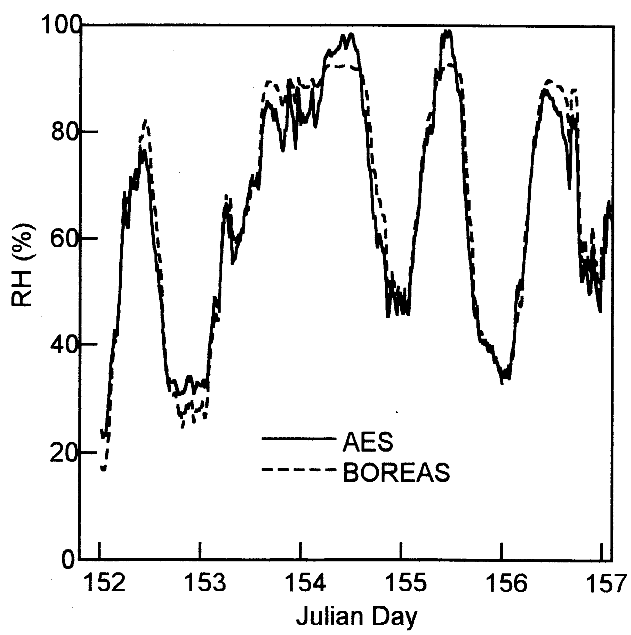

Figure 5. Comparison of two RH sensors for the first 5 days of June 1994.

3. Discussion

Accurate measurement of humidity has long been a problem in meteorology, and this comparison only confirms it. The difference we see here in Figure 3 is important to physical modeling, as it would suggest a different early morning balance between the surface evaporation and the mixing down of dry air from above by entrainment as the boundary layer deepens. The difference is also important to global or regional data assimilation systems, since they use the operational humidity data. For example, the present operational European Centre model uses the bias between a humidity analysis at synoptic times every 6 hours and a short-term model forecast to "nudge" soil moisture. Fortunately for BOREAS, the morning peak in the operational data at 1500 UTC is between the analysis times of 1200 and 1800 UTC! Further comparisons with the humidity sensors used by the BOREAS flux towers are planned.

Acknowledgments. AKB was supported by NASA Goddard Space Flight Center under contract NAS5-32356. The Saskatchewan Research Council was funded under contract to NASA.

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(Received June 13, 1996; revised September 3, 1996; accepted September 10, 1996.)